in the Number 2 bed may have been drowned in floods; more, doubtless, died the natural deaths of the wilderness.

Sometime during this episode man appeared on the scene. Some of his bones and implements were buried by the drifting sand and became part of the bone bed. Others, remaining longer on the surface, were eventually covered by the stream and bog deposits that I shall now describe.

Lying upon the bone bed and effectually sealing it from the accidental intrusion of objects from above, are patches of fresh-water deposits that have been called the "Number 3 beds." At Vero and Melbourne the "Number 3 beds" are swamp and stream deposits that consist of muck and partly decomposed roots, bark, and leaves, interstratified with yellowish sand. Fresh-water mussel shells are abundant in the stream deposit at Melbourne. At New Smyrna, according to Doctor Gidley, there is no clearly-defined stream channel, but the bone bed, Number 2, is covered by a peaty bog. It is very unlikely that human bodies could have been buried in the bone bed by sorrowing relatives without leaving easily discoverable traces of the hole in the peat bed through which the remains of the late lamented were interred. Neither Doctor Sellards nor Doctor Gidley has detected any evidence of such intrusion. The human bones must have been there before the peat bed accumulated.

The Number 3 beds are obviously recent. The accumulation probably began immediately after a rise of sea level that drowned the valleys of Van Valkenburg Creek at Vero, Crane Creek at Melbourne, and St. Johns River at Jacksonville on the East Coast and produced Charlotte Harbor and Tampa Bay on the West Coast. The fresh-water deposits continued to accumulate until the process was interrupted by the cutting of drainage canals a few years ago. How many years elapsed during this interval I am not prepared to say. Estimates based upon the thickness of the Number 3 beds (about 5 feet at Melbourne) and the rate of accumulation of various kinds of fresh-water deposits might be attempted but there are so many variable factors that such estimates would not be very reliable.

The topography of the region throws some light on the probable ages of the beds. The fossil-bearing localities near Vero, Melbourne, and New Smyrna are all on a nearly level plain that extends inland a distance of 20 or 25 miles and stands chiefly between the altitudes of 20 and 30 feet above sea level. They lie back of a low sandy ridge whose crest is less than 40 feet above sea level in the vicinity of Melbourne but which is more conspicuous and perhaps somewhat higher

near Vero. This ridge probably is a former beach ridge that marks a temporary position of the shore during emergence of the sea bottom.

The plain that I have just described is the lowest well-defined member of a series of terrace plains that front the Atlantic Ocean from Delaware Bay to the Straits of Florida. In Georgia it is called the Satilla terrace. It probably corresponds to the Chowan terrace of North Carolina and to the Talbot terrace of Maryland. It obviously is an emerged sea bottom, for it is floored with sea shells. Before its emergence the shore line stood at an altitude of approximately 60 feet above the present sea level. Farther north in Florida and in Georgia, still older shore lines can be traced on topographic maps at altitudes 100 and 160 feet above sea level and there are even higher terraces that also may be marine.[4]

These ancient shore lines and the flight of step-like terraces that lie between them are supposed to represent different stages of the Pleistocene epoch. The highest terrace, being presumably the first to emerge, is the oldest; and the lowest, being most recently under water, is the youngest.[5] The Satilla terrace with the 60-foot shore line does not correspond to the very latest stage of the Pleistocene, for, although the Satilla is the lowest *well-defined* terrace, there appears to be a still lower and younger terrace with a shore line 20 or 25 feet above sea level and bordered by the somewhat higher beach ridge mentioned above. Stephenson has recognized such a low terrace in North Carolina and named it the Pamlico. Wentworth has detected it also in Virginia.

Doctor Hay has recently published the statement that none of the terraces, not even the one on which the fossil bones are found, is marine because they do not contain any marine fossils.[6] This statement seems surprising in view of the fact, well known to Doctor Hay, that the Anastasia formation or Number 1 bed is composed chiefly of sea shells. He is evidently confusing the deposits on the terrace with the terrace

[4] For a description of the terraces in Georgia see C. WYTHE COOKE. *Physical geography of Georgia.* Georgia Geol. Survey Bull. **42**: 21–35. 1925.

[5] Melting of the existing polar ice caps would raise the level of the sea to a height comparable to that of the highest shore line definitely recognized in Florida. If the land has remained stationary and the elevated shore lines correspond to inundations caused by melted ice, then deglaciation during the interglacial stages of the Pleistocene was more complete than now, and the height of each shore line is a measure of the extent of deglaciation during the corresponding period. If, as is commonly assumed, the highest terrace is the oldest and the lower terraces are progressively younger, the highest terrace should have been under water during the first interglacial stage or before the first glaciation and the lowest terrace during the last interglacial stage. During the intervening glacial stages sea level may have been depressed below its present position.

[6] O. P. HAY. This JOURNAL **18**: 236. 1928.

itself—the table cover with the table. A marine terrace is an emerged sea bottom. The marine terrace at Vero and Melbourne, strictly speaking, is the surface of the Number 1 bed, which was the old sea floor. The Number 2 and Number 3 beds, which are nonmarine, are *on* the terrace. They correspond to the table cover.

It is true, as Doctor Hay contends, that no sea shells have been found on the higher terraces, but that fact does not outweigh other evidences of their marine origin. The marine deposits on the higher terraces consist only of a thin veneer of loose sand. What chance would sea shells embedded in porous sand have of resisting through many centuries the corrosive action of organic acids in the soil? Great caves have been dissolved in solid limestone by rain water in no longer time than the higher terraces have been above the sea.

What agency but the sea could distribute a cover of fine white sand over a plain several thousand square miles in extent on the divide between the Atlantic Ocean and the Gulf of Mexico? What agency but the sea could build on the outer edge of this plain a sand bar 130 miles long and 2 to 4 miles wide extending parallel to the present coast and 40 feet higher on the seaward side than on the landward side? I refer to the Okefenokee terrace and Trail Ridge.

Let us now trace the principal events in the history of Florida during the Pleistocene epoch. Early in Pleistocene time, possibly during the first interglacial stage, much of the peninsula of Florida was submerged beneath the sea and the shore line stood at the 160-foot level. A long sand bar, now Trail Ridge, was built northward into Georgia from an island and shut off a sound similar to the present Pamlico Sound of North Carolina. Later the sea withdrew to the 100-foot level, Trail Ridge became the sea shore, and the sound was converted into Okefenokee Swamp. Once more the sea lowered, and came to rest at an altitude of only 60 feet above its present level. The shore line then stood at most places west of the present course of St. Johns River. The sites of Vero, Melbourne, and New Smyrna were still under water.

As a result of the next oscillation the sea halted about 20 feet above its present level. Shell-covered barrier beaches separated from the mainland by lagoons appeared above the waves, were covered with vegetation, and became the home of a great variety of land animals and turtles. Sand blown from the beach gradually silted up the lagoons and accumulated in hollows in the lee of the beach ridge. Man at last appeared. This was the period during which the bone beds at Vero, Melbourne and New Smyrna accumulated.

The next event appears to have been a further emergence of perhaps 60 feet. The sea retreated to a position about 40 feet below its present level, the lagoons were emptied, and streams began vigorously to erode their channels.

Erosion had not progressed very far before it was checked by a submergence that drowned the lower courses of the streams and brought the sea to its present level. This event may logically be considered the beginning of the Recent epoch.

The more important facts of history and stratigraphy can be summarized as follows: Bones of prehistoric animals of early Pleistocene aspect and human bones were buried by sand blown from the neighboring seashore and deposited on the Satilla terrace, a newly-emerged sea bottom. Further emergence of 60 feet removed the shore to such a distance that deposition of sand ceased and streams began to trench the deposits already formed. Partial submergence then choked the lower courses of the streams and made them boggy.

Deposits of three ages have been distinguished: First, a Pleistocene marine shell marl, known as Number 1 bed. Second, a Pleistocene bone bed with human remains, called Number 2 bed. Third, Recent stream and bog deposits called Number 3 beds.

As to the age of the bone bed: In view of the long succession of Pleistocene events that preceded the emergence of the Satilla terrace on which it rests, it seems scarcely possible that the bone bed can be as ancient as the Aftonian or first interglacial. On the other hand, it can hardly be the very latest Pleistocene, for we have to allow time at the close of the Pleistocene for an uplift and a depression. If the emergence that followed the accumulation of the bone bed was contemporaneous with the Wisconsin glaciation, the bone bed might well have been formed during the Peorian or fourth interglacial stage.

The purpose of this paper has been simply to describe the stratigraphy of the region in which human remains have been found and to endeavor to ascertain the ages of the various beds. I have given no details regarding the manner of occurrence of the human bones and artifacts because I have not been so fortunate as to find any human remains myself nor to be present when they were discovered by others. I have assumed that the association of human remains with the Pleistocene fauna as reported by Dr. Gidley is so well authenticated that there seems little reason to doubt that man actually lived in Florida during the latter part of the Pleistocene.

Is it after all so surprising to find him there? Need we assume for

man a more rapid evolution than that of other almost equally complex mammals? Nearly all of the existing species of mammals are survivals from the Pleistocene. The essential difference between the Pleistocene and the Recent faunas is one of quantity rather than kind. Many species became extinct during or at the close of the Pleistocene, but few new species or subspecies originated during that time. One would therefore expect to find that the Pleistocene progenitors of the modern man are indistinguishable from ourselves. Other contemporary races of primitive man that are now extinct represent collateral lines and are not our ancestors.

The presence of man in America, assuming that he originated in the old world, is no more difficult to explain than the presence here during by-gone ages of camels, horses, elephants, rhinoceroses, and other genera that are now restricted to Africa or Asia.

PALEONTOLOGY.—*Characteristic mammals of the Early Pleistocene.*[1] OLIVER P. HAY, Washington, D. C.

For the writer the Pleistocene is the equivalent of the Ice Age. We may say that it began when the first ice sheet, the Nebraskan, had pushed southward to about the 55th degree of latitude. It had perhaps even then begun to disturb the ancient drainage systems. It ended when the Wisconsin glacier had retreated to the same latitude, opening up the main river systems of our times. Within that interval there had occurred momentous changes in the physiography of our continent, in its climates, and in its highest forms of animal life.

I wish to discuss especially the composition of the mammalian life of the Pleistocene and some of the changes which it underwent.

The kinds of mammals that existed on our continent during the late Pliocene are not sufficiently well known. We know, however, that there were present a few edentates, various carnivores of dog-like and cat-like forms, mastodons, tapirs, horses (possibly not yet *Equus*), peccaries, camels, and antelope-like hoofed animals. After the close of the Pliocene no doubt some of those mammals, somewhat modified, lived on into the Pleistocene. We are sure that a few of the edentates did so; also some of the tapirs, peccaries, camels, and some of the early horses.

About the beginning of the Pleistocene a passage was opened up

[1] Received July 20, 1928.

between Asia and North America. Over this many kinds of Old World mammals entered our continent. Elephants of perhaps several species, new mastodons, bisons, musk-oxen, deer, moose, wolves, tigers, possibly horses and camels, descendants of former migrants from this country into Asia, pressed in and spread over the land. About the same time, perhaps a little earlier, a highway was established between South America and North America and our land was invaded by the strange fauna of the southern continent. The most conspicuous of these animals belonged to the order of Edentates, and consisted of huge ground-sloths, armadillos, and glyptodons. More than a dozen genera of these edentates have been described; and they varied in size from that of the existing Texan armadillo to that of an elephant. Our early Pleistocene mammalian fauna was, therefore, a product of three continents and it was a fauna probably more abundant in numbers and more diverse in species than any other known.

About the genera and species of mammals which existed in our country during the first glacial stage we know little or nothing, I mean little that is derived from actually discovered remains. We can only judge as to their general nature from those which preceded them and those which followed them.

I shall now attempt to show that certain important elements of the mammals I have mentioned existed in our country in what is believed to be the first interglacial stage.

Along the Missouri River, from the northwestern corner of the State of Missouri to the mouth of Sioux River and along this to the northwestern corner of Iowa, at many localities, have been discovered deposits, gravels and sands, intercalated between the first (Nebraskan) and the second (Kansan) drifts. These gravels and sands are known as Aftonian deposits. In these have been discovered a considerable number of fossil mammals. In one gravel pit near the town of Missouri Valley, 18 species have been reported. Of these, 90 percent are extinct. They represent eight families and twelve genera. There are two species of ground-sloths (*Megalonyx* and *Mylodon*), three species of elephants, one or two of mastodons, four species of horses, at least one species of camel, a moose, a bison, a musk-ox, a goat, the existing bear, and a beaver.

In this one pit, therefore, have been found representatives of 8 families of mammals, *Megatheriidae* (ground-sloths), *Castoridae* (beavers), *Elephantidae* (elephants), *Equidae* (horses), *Camelidae* (camels), *Cervidae* (deer), *Bovidae* (oxen), and *Ursidae* (bears).

Near Akron, Plymouth County, were found two teeth of *Stegomastodon mirificus* in Aftonian deposits. In a deposit of the same stage, at Mapleton, Harrison County, was found a fine tooth of *Elephas imperator*. At Afton, Iowa, were collected foot bones and a tooth of *Hipparion*. At Rockport in northwestern Missouri, in the Aftonian sands and gravels, were found a foot-bone of a horse, a tooth of a camel, and a molar tooth of *Hipparion*.

Near the present post-town of Peters, Sheridan County, in northwestern Nebraska, near Niobrara River, in a deposit of sand lying between 50 and 100 feet above the little tributary of the river, were collected many years ago about 20 species of mammals. Of these at least 70 percent are extinct. The fossils represented 13 families and 16 genera. These include two genera of ground-sloths, two dogs, an extinct genus of bears (*Arctotherium*), a prairie dog and a musk-rat, a field mouse, two elephants, one of them *Elephas imperator*, an extinct genus of peccaries, three species of camels, two species of prong-horn antelopes, one possibly the existing species, the other the extinct *Capromeryx furcifer*. The bed of sand containing these fossils is about 12 feet thick and overlies late Tertiary deposits. Since the bed was laid down, Niobrara River has cut its valley nearly 100 feet deeper.

I ask you now to consider Pleistocene fossil mammals which have been found in the canyon of Tula Creek, Briscoe and Swisher Counties, Texas. During probably the early part of the Pleistocene, by a quickening of a stream, approximately 100 feet of deposits were removed from the Miocene. Then came a change either in a reduced slope of the country or in a smaller amount of water or both, and deposition recommenced. There was laid down first about 30 feet of coarse sand, over this 15 feet of bluish clay, then again course sand, and finally 25 feet of fine white sand. This variation in the materials implies changes in climate and of elevation, and consequently this deposition of 90 feet of sand and clay required a long time. Then occurred a more momentous change in affairs. The region must have been considerably elevated as also the country west of it, for extensive cutting began. This continued until a broad valley had been eroded through all of that 90 feet of Pleistocene materials, then through the Miocene and down into the Triassic clay below. That canyon so cut is, less than 10 miles farther down, 400 or 500 feet deep. We can not doubt that those deposits belong to an early stage of the Pleistocene.

Now in the first coarse sand laid down and in the last stratum of fine sand have been found numerous specimens of Pleistocene mammals.

About 20 species have been collected. These include a ground-sloth (*Mylodon*), a glyptodon, two elephants, one being *Elephas imperator*, from four to six species of horses, a peccary, four species of camels and two species of dogs. All of the species collected are now extinct.

I ask you now to consider a fourth important locality, one whose geology certifies to the age of the fossils discovered.

Frederick, Tillman County, is in southwestern Oklahoma, about 12 miles north of Red River. From the town there runs northward for about ten miles a prominent ridge, and this near the town stands about 100 feet above the adjacent country. In one side of this ridge a sand and gravel pit has been opened and is being extensively operated. The ridge is found to be a filled-up and abandoned river bed, probably that of the ancient North Fork of Red River. The filling consists of, first, a stratum a foot or two thick, of broken rocks and gravel cemented by carbonate of lime, forming a mass of considerable hardness. Above this is a rather hard sandstone of about the same thickness. This is overlain by some ten to fifteen feet of compact sand and gravel; while above all comes about three feet of a red clay. The whole rests on a red clay of Permian age. At present the North Fork runs about ten miles west of Frederick and at a level of 200 or more feet lower down.

Now principally in the lowest cemented layer, but to some extent in the compact sand, have been discovered numerous fossil bones of mammals. Since they were buried there the river valley was filled and choked up, the river diverted into other channels, and the immediate region has been eroded away more than 100 feet, while further west probably more than 200 feet. It will be understood at once that a very long time must have been required to accomplish that work. Inasmuch as the animals found there are in general the same as those found in the three other localities mentioned it is concluded that the time of their burial was during the first interglacial stage. The fossils collected consist of a megalonyx, a mylodon, a mastodon, a glyptodon, three or four horses, a large tapir, a large and a small camel, a peccary, an elephant more primitive than *E. imperator*, two other elephants, a mastodon which appears to belong to the long-jawed genus *Gomphotherium*. All of the species are extinct.

Collecting together then the animals found in the western Iowa localities (1), that on Niobrara River (2), that in Tula Canyon (3), Texas, and that at Frederick (4), Oklahoma, we have the following list:

Megalonyx jeffersonii 1, 2, 4
Mylodon harlani 1, 2, 3, 4
Glyptodon petaliferus 3, 4
Equus complicatus 1, 3, 4
E. niobrarensis 1, 2
E. laurentius 1
E. scotti 3
E. excelsus 1, 2, 3
E. calobatus 3
E. tau ? 3
E. semiplicatus 3
Tapirus haysii 4
Platygonus compressus 3
P. sp. indet. 2, 4
Camelops huerfanensis ? 3
C. vitakerianus 2
C. macrocephalus 3
C. kansanus 2
C. hesternus 3
C. niobrarensis 4
Lama sp. nov. 4
Camelus americanus 2
Eschatius conidens 3
Alces shimeki 1
Capromeryx furcifer 2
Antilocapra americana ? 2
Symbos cavifrons 1
Aftonius calvini 1
Bison sp. indet. 1
Elephas haroldcooki 4
E. imperator 1, 2, 3
E. columbi 1, 2, 3, 4
E. boreus 1, 4
E. primigenius ? 4
Mammut americanum 1
M. progenium 1
Stegomastodon mirificus 1
Gomphotherium sp. nov. 4
Castor canadensis 1
Castoroides ohioensis ? 2
Microtus sp. indet. 2
Ondatra nebrascensis 2
Thomomys sp. indet. 2
Cynomys ludovicianus 2
Lepus sp. 4
Ursus americanus 1
Arctotherium sp. indet. 2
Ænocyon dirus 3
Canis occidentalis ? 2
C. texanus 3
C. latrans 2
Smilodon nebrascensis 2

In this list there are included more than 50 species which appear to have lived during the first interglacial stage. I do not see how this conclusion can be escaped. Most of those of the list represent mammals which are to be found in deposits all over the Great Plains into Texas and Mexico and many of them are found in Florida and South Carolina. When white men discovered this continent the great majority (80 percent) of the animals here listed no longer existed.

Now the question arises: Did all of these animals that are now extinct, and many others not here mentioned, live on until near or into the Recent epoch and then suddenly disappear, or did the extinctions occur at various times during the first interglacial stage and since that time?

What can we learn about the longevity of mammalian genera and species on comparing them with genera and species of mollusks? Several genera of mollusks have persisted ever since the Jurassic; many more from the Cretaceous. The oldest living genus of mammals is, I think, *Didelphis*, the opossum, and this comes down to us from only the Eocene. Following Matthew's list[2] we find that of

[2] Bull. U. S. Geol. Surv. No. 361.

90 Miocene genera only 11 now exist (12 percent); of species none. With few exceptions the Miocene species do not continue from one formation to the next. In a geological sense, therefore, mammalian genera and species are short-lived. This being true I hold that it is improbable that all of the species of the list presented lived until the close of the Pleistocene. In that first interglacial stage there were thrown together three incongruous faunas, and it was inevitable that in the struggle for existence some would succumb. This would have happened even if the physical environment were favorable, but with the changes resulting from three or four glacial stages and two or three interglacial stages extinctions would be multiplied.

The fact that the collections from the older Pleistocene deposits show a much higher percentage of extinct forms than from known later ones is evidence that the extinctions occurred at all times. Had all the first interglacial species lived until the end of the Pleistocene, collections from all of the stages would show approximately the same percentage of extinct species.

The history of the Pleistocene animals of Europe shows that the older deposits contain a higher proportion of non-existing species, the majority or all of the earliest deposits being extinct.

Out of the list which has been presented I select the following species as being a part of those of which we find no traces after the close of the first interglacial stage, or at least, after the Kansan glacial stage.

Glyptodon petaliferus
Equus niobrarensis
E. laurentius
E. excelsus
E. semiplicatus
E. calobatus
Camelops huerfanensis
C. hesternus
C. niobrarensis
C. vitakerianus
C. macrocephalus
C. kansanus
Eschatius conidens
Camelus americanus
Elephas haroldcooki
E. imperator
Smilodon nebrascensis

To these I add the following because they have been found associated with those of the number just given and are evidently of the same geological age.

Smilodon floridanus
Neochœrus pinckneyi
Stegomastodon mirificus
Megatherium mirabile
Chlamytherium septentrionale

Here are listed 22 species of large and important animals of which the writer affirms that they have not been found at any locality the